A draft plan for: Tropical Composition, Clouds and Climate Coupling (TC4) Experiment

Planning Group:

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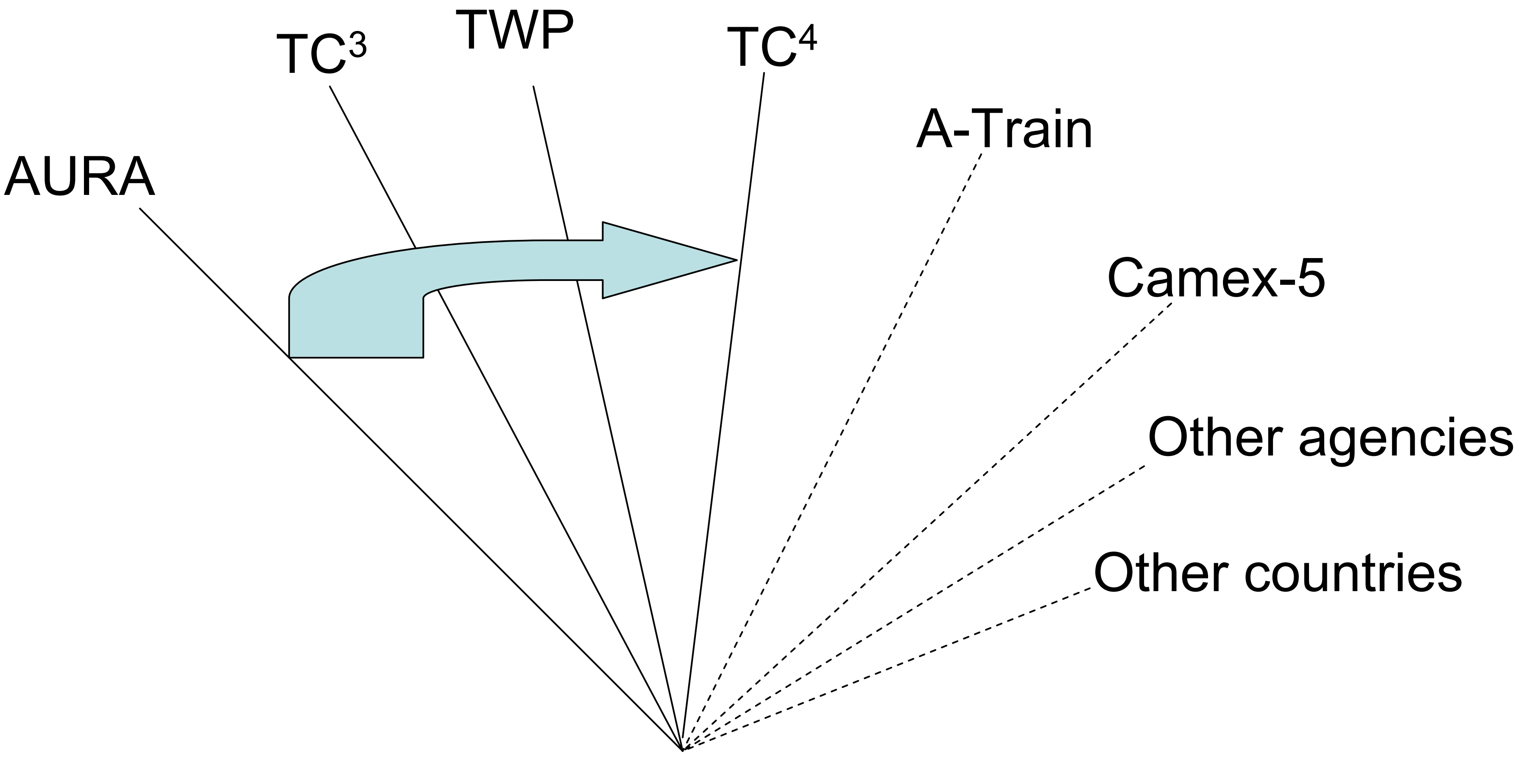
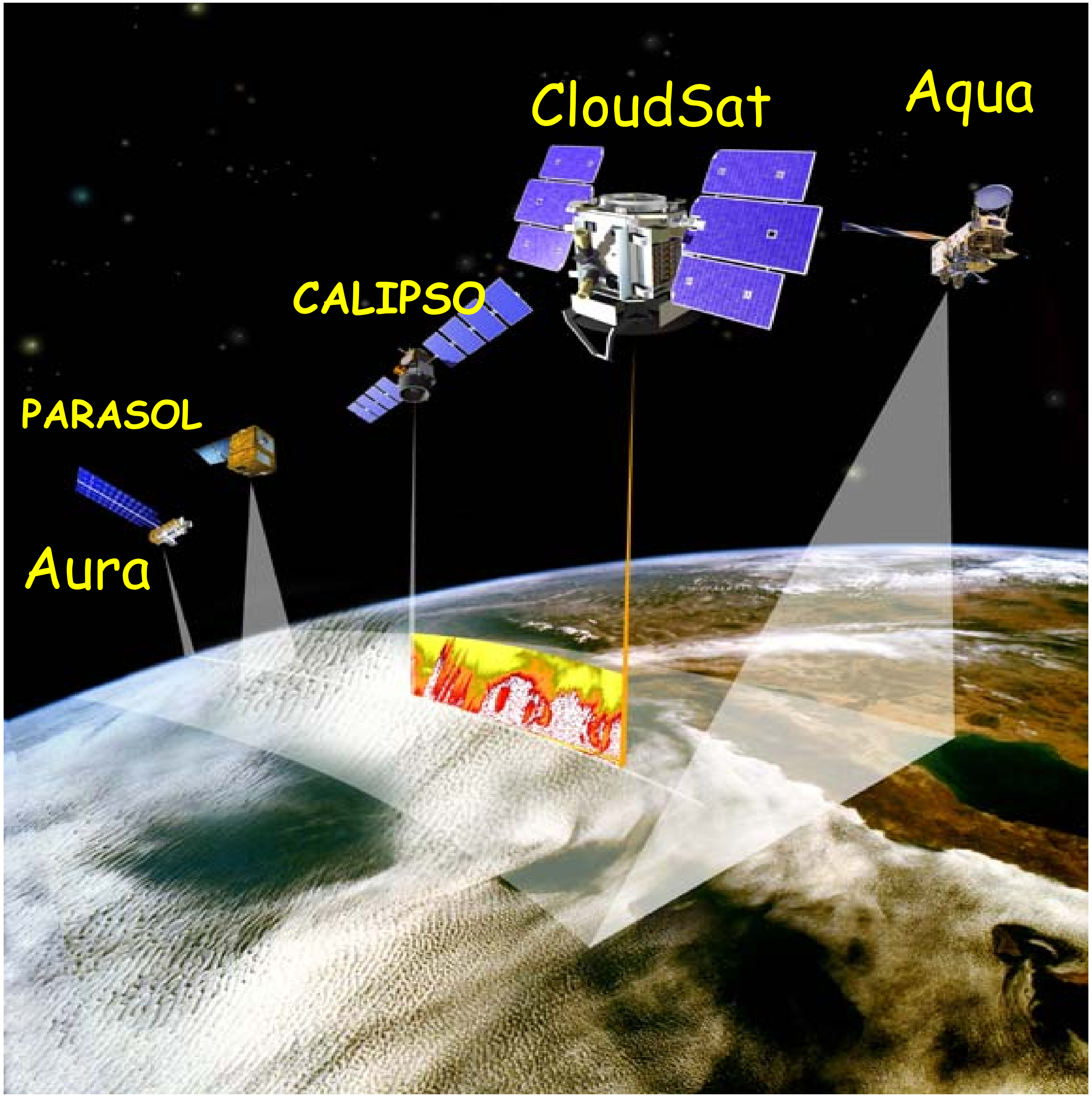
Evolution of plan





The A-Train

A-Train Aqua

Spacecraft	Payload	Characteristics	Clouds and aerosol
AQUA Lead constellation spacecraft	MODIS	36 channel visible radiometer, 2300-km wide swath, resolution 0.25 to 1 km.	Land, ocean and atmosphere. Cloud and aerosol optical depths and particle size information, + cloud emissivity, cloud-top height.
	AIRS/AMSU-A /HSB	IR/microwave sounders. Swath of ± 50^{o}, resolution of IR sounder ~10km	Temperature and moisture profiles in clear atmosphere. Some cloud properties.
	AMSR-E	6 channel microwave radiometer. 1445 km swath, asymmetric FOV with variable resolution from ~6X4km (89 GHz) to 43X75km (6 GHz).	Liquid water path, column water vapor, liquid precipitation., principally confined to ocean regions.
	CERES	Broad band and spectral radiances, resolutions at nadir Š 20km	Top-of-atmosphere radiation budget. Time-mean fluxes and instantaneous fluxes

Stephens et al., 2002

A-Train CloudSat/Calipso/Parasol

Spacecraft	Payload	Characteristics	Cloud and aerosol products
CLOUDSAT Lags Aqua by a variable amount but less than 120 sec	94 GHz radar (CPR)	500m vertical range gates from surface to 30km. High sensitivity, FOV approximately 1.4 km.	Cloud, liquid and ice water content profiles, precip. obtained by combining radar with AQUA measurements (MODIS, AMSR-E, CALIPSO lidar.)
CALIPSO Separation is maintained by CloudSat. Lags CloudSat by 15 $\pm$ 2.5 sec.	Lidar (CALIOP)	532 and 1064 nm channels with depolarization. FOV of approximately 300m and 70m resolution.	Cloud profile for upper tropospheric clouds. Optical depth of thin cirrus. Aerosol profiles optical depth estimates. Aerosol requires averaging over 10s km especially in daylight.
	IIR	3 channel IR radiometer with a FOV of 1km, swath 64km.	Cirrus cloud optical properties.
PARASOL Lags CALIPSO by ~ 2 minutes	POLDER	9 channel polarimeter with channels in the visible and near infrared. Resolution of 5m, swath of ~ 400km.	Cloud and fine-mode aerosol optical depths and particle sizes.

Stephens et al., 2002

A-Train-Aura

AURA Lags AQUA by about 15 minutes	HIRDLS	IR Limb Sounder	Trace gases and stratospheric aerosol
	MLS	Microwave Limb Sounder	Trace gases, ice content of thin upper tropospheric cloud.
	TES	IR imaging spectrometer, 0.5X5 km resolution, narrow swath and variable pointing	Trace gases, could also provide high spectral resolution data on clouds
	OMI	UV grating spectrometer, 13X24 km resolution	Ozone and aerosol index.

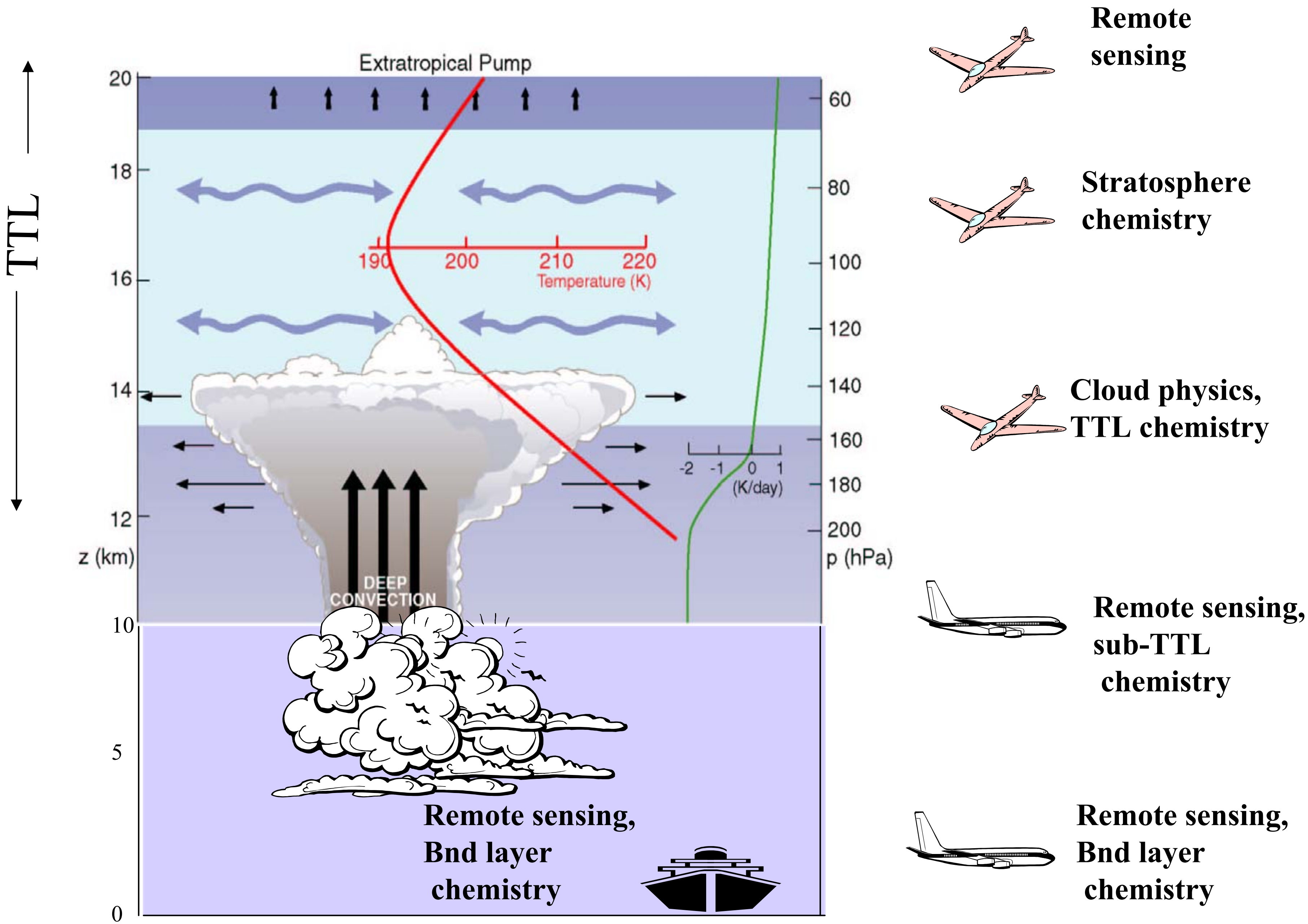
Stephens et al., 2002

Major questions addressed by TC^4

Scientific question	Mission
1. What mechanisms maintain the humidity of the stratosphere? What are the relative roles of large scale transport and convective transport and how are these processes coupled?	TC^3-TWP
2. What are the physical mechanisms that control (and cause) long-term changes in the humidity of the upper troposphere in the tropics and subtropics?	TC^3-TWP
3. What controls the formation and distribution of thin cirrus in the Tropical Tropopause layer, and what is the influence of thin cirrus on radiative heating and cooling rates, and on vertical transport?	TC^3-TWP
8. How can space-based measurements of geophysical parameters, particularly those known to possess strong variations on small spatial scales (e.g., H_2O, cirrus), be validated in a meaningful fashion?	TC^3-TWP

Major questions addressed by TC^4

Scientific question	Mission
4. What are the chemical fates of short-lived compounds transported from the tropical boundary layer into the Tropical Tropopause layer. (i.e., what is the chemical boundary condition for the stratosphere?)	TC^3
5. What are the mechanisms that control ozone within and below the Tropical Tropopause Transition layer?	TC^3
6. How are cirrus anvil properties related to the intensity and scale of convection?	TWP
7. How do cirrus anvils evolve over their life cycle? How do they impact the radiation budget and ultimately the circulation?	TWP



Sampling strategy

Instruments on boundary layer platform. (Boundary layer to ~5 km)

Observation	Priority	Instrument status
O_3	1	X
H_2O vapor	1	C
CCN	1	C
Aerosol, IN composition	1	C
Aerosols-size, shape, phase	1	C
Precipitation Doppler Radar	1	C
Longwave Radiation and Solar Spectral Irradiation	1	C
CO, CH_4	1	C
CO_2	2	X
N_2O, CFCs	3	X
SF_6	4	X
NO	1	X
HNO_3, PAN, NO_2	1	X
Acetone, HCHO, and peroxides	1	X, D
NMHC, including short-lived tracers, HCFCs, halocarbons	1	X
T, winds, P	1	C
^{210}Pb, ^{222}Rn, ^{85}Kr	4	D
GPS downlink	1	D

NOTES: Priority:1=Central to TC^4 goals, 2= Very Important to goals, 3=Important, 4= useful to have. Status: X = exists/flown in previous missions, C= exists/flown on Crystal-FACE, D = instrument development required.

Instruments on upper troposphere aircraft. (altitude range from 5-12 km.)

Observation	Priority	Inst. status
O_3	1	C
H_2O vapor	1	C
H_2O total	1	C
Total H_2O isotopes	1	D
IN, CCN	1	C
Aerosol, IN composition	1	X
Clouds, Aerosols, size, shape, phase	1	C
Precip&Cloud radar	1	X
Water vapor lidar	1	X
Ozone lidar	1	X
Microwave temperature profiler	1	C
Temperature lidar	3	D (day)
Cloud lidar	1	X
IR and Solar Spectral Irradiation	1	X
Cloud extinction	1	C
CO, CH_4	1	X
N_2O, CO_2	2	X
SF_6	4	?
NO	1	X
HNO_3, PAN, NO_2	1	X
HO_x	1	X
Acetone, HCHO, and peroxide	1	X
NMHC, including short-lived tracers,	1	X
HCFCs, halocarbons	2	X
^{210}Pb, ^{222}Rn, ^{85}Kr	4	D
T, winds, P	1	C
GPS downlink	1	D

NOTES: Priority:1=Central to TC^4 goals, 2= Very Important to goals, 3 = Important, 4= useful to have. Status: X = exists/flown in previous missions, C= exists/flown on Crystal-FACE, D = instrument development required.

Instruments on TTL aircraft. (about 12-17 km, in regions with extensive cloud cover).

Observation	Priority	Inst. status
O_3	1	C
H_2O vapor	1	C
H_2O total	1	C
Total H_2O isotopes	1	C
Aerosol, IN composition	1	C
Clouds, Aerosols, size, shape, phase	1	C
Clouds forward scanning lidar	2	D
IR and Solar Spectral Irradiation	1	X
Cloud extinction	1	C
CO, CH_4, HCl	1	C
N_2O, CO_2, CFCs	2	C
SF_6	3	X
HO_x	1	X
NO_x	1	C
BrO, ClO	2	X
IO	3	D
HNO_3, PAN, NO_y	2	C
$ClNO_3$	4	D
Short-lived organics	1	X
Acetone, HCHO, peroxide	2	D
SO_2	2	D
T, winds, P	1	C
^{210}Pb, ^{222}Rn, ^{85}Kr	4	D
GPS downlink	1	D

NOTES: Priority:1=Central to TC^4 goals, 2= Very important to goals, 3 = Important, 4= useful to have. Status: X = exists/flown in previous missions, C= exists/flown on Crystal-FACE, D = instrument development required.

Instruments on stratosphere profiling aircraft (This aircraft must be capable of profiling to altitudes as low 12 km.)

Observation	Priority	Instrument status
O_3	1	X
H_2O vapor	1	X
H_2O total	1	X
Total H_2O isotopes	1	X
Aerosol, IN composition	2	C
Clouds, Aerosols, size, shape, phase	1	C
Cloud extinction	2	C
CO, CH_4, HCl	1	C
N_2O, CO_2, CFCs	2	C
SF_6	3	X
HO_x	1	X
NO_x	1	C
BrO, ClO	2	X
IO	3	D
HNO_3, PAN, NO_y	1	C
$ClNO_3$	4	X
Short-lived organics	1	C, D
Acetone, HCHO, peroxides	2	D
SO_2	3	D
T, winds, P	1	C
^{210}Pb, ^{222}Rn, ^{85}Kr	4	D
GPS downlink	1	D

NOTES: Priority:1=Central to TC^4 goals, 2= Very important to goals, 3=important, 4= useful to have. Status: X = exists/flown in previous missions, C= exists/flown on Crystal-FACE, D = instrument development required.

Instruments on remote sensing aircraft (needs to operate well above cloud tops)

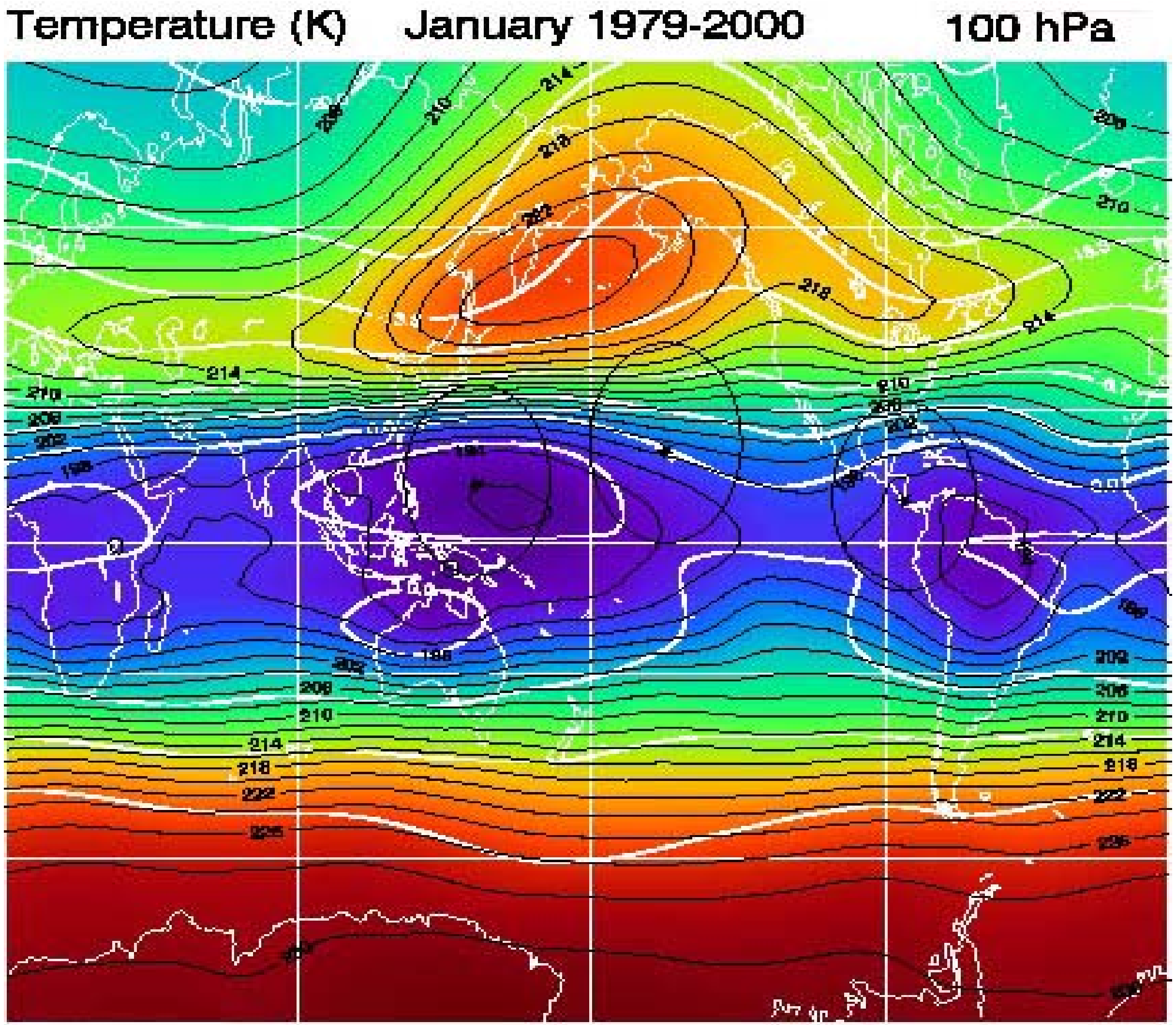
Observation	Priority	Inst status
Precip/Cloud radar	1	C
Small Water vapor lidar	2	D
Small Ozone lidar	1	D
Microwave profiler	1	C
Temperature lidar	3	D
Cloud lidar	1	C
Outgoing IR Radiation and Solar Spectral Irradiation	1	C
Far IR spectrometer, Microwave radiometer	1	C
Sub mm radiometer	1	C
Dropsondes	1	C
Visible spectral radiometers, imagers, scanners for ground truthing	1	C
DOAS Profiler	1	D
T, winds, P	1	C
GPS downlink	1	D

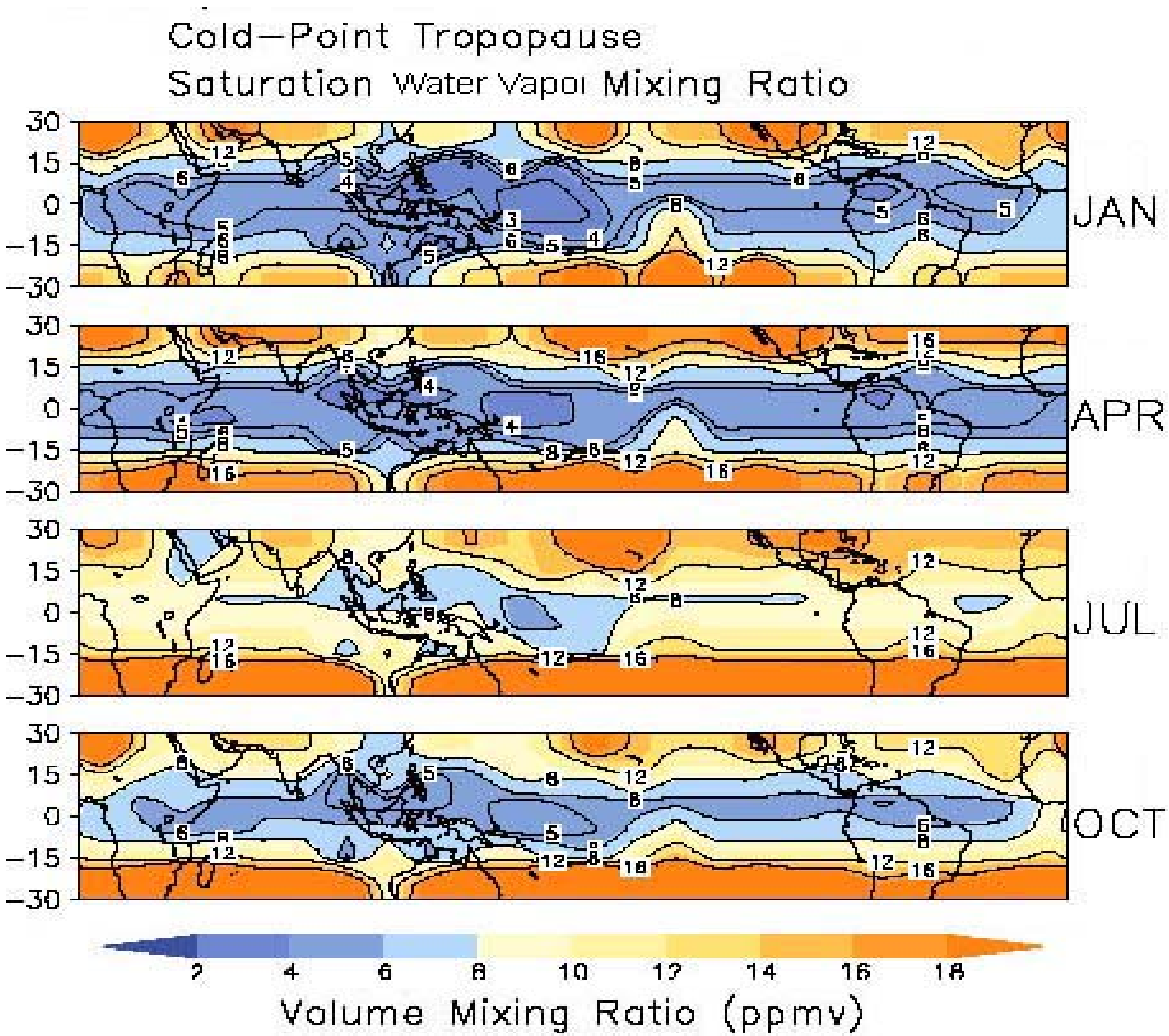
NOTES: Priority:1=Central to TC^4 goals, 2=Very Important to goals, 3=important, 4= useful to have. Status: X = exists/flown in previous missions, C= exists/flown on Crystal-FACE, D = instrument development required.

Criteria for NH winter experiment

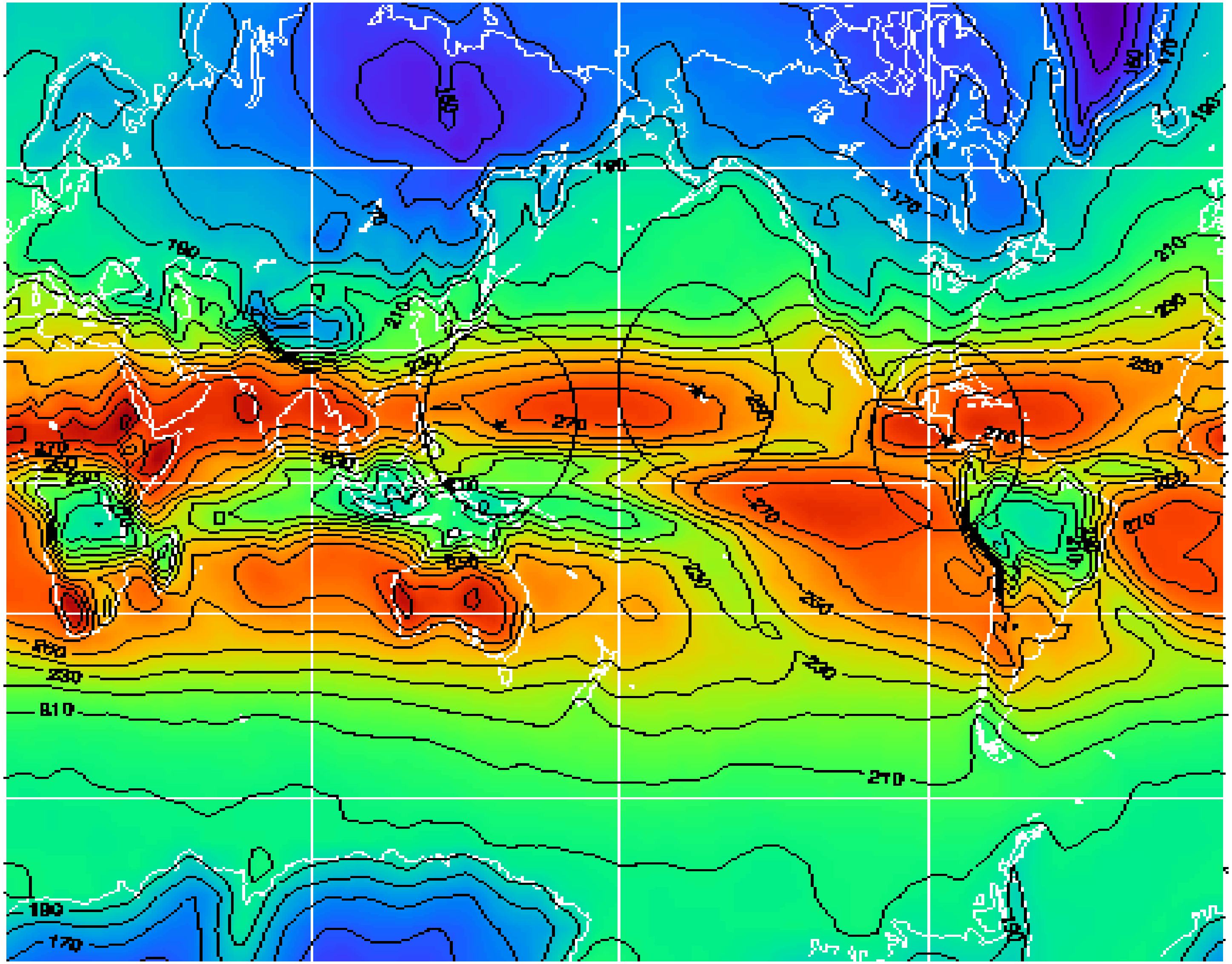
location	Singapore	Guam	Darwin	Kwajalein	Hawaii	Costa Rica
Lat/long	1.3°N, 103.9°E	13.4°N, 144.4°E	12.5°S, 130.6°E	9°N, 168°E	21.3°N, 157.9°W	10°N, 276°E
runway/ hangers	yes	yes	yes	No, runway too short, Hangers space limited	yes	yes
Close to tropopause cold pool?	yes, end of range	yes	no	yes	no	Yes, secondary
Close to high maritime clouds?	maybe	yes, end of range	yes	yes	no	no
Close to low water vapor regions?	maybe	yes	no	yes	no	Yes, secondary
Madden-Julian Oscillation	yes	yes	yes	yes	maybe	slight

Climatological 100 mbar Temperature in Jan

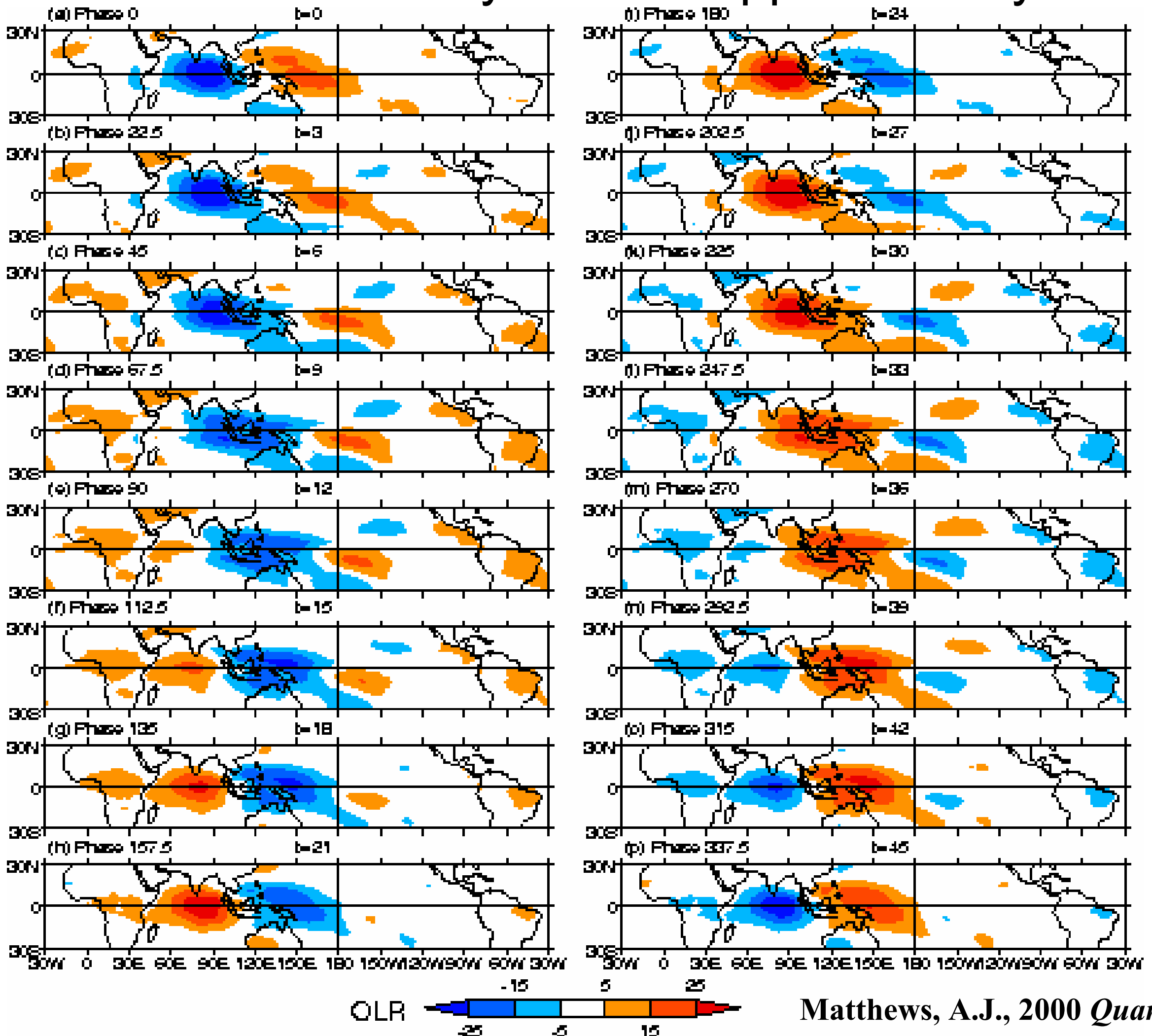



Cold-Point Tropopause
Saturation Water Vapor Mixing Ratio
JAN
APR
JUL
OCT
30
15
0
−15
−30
2
4
6
8
10
12
14
16
18
Volume Mixing Ratio (ppmv)

Outgoing Longwave Radiation (W/m ^ 2) January 1979-1995



Typical Madden Julian Oscillation life cycle. OLR anomalies (legend is in W m-2). The images are spaced approximately 3 days apart and one whole cycle lasts approximately 48 days.

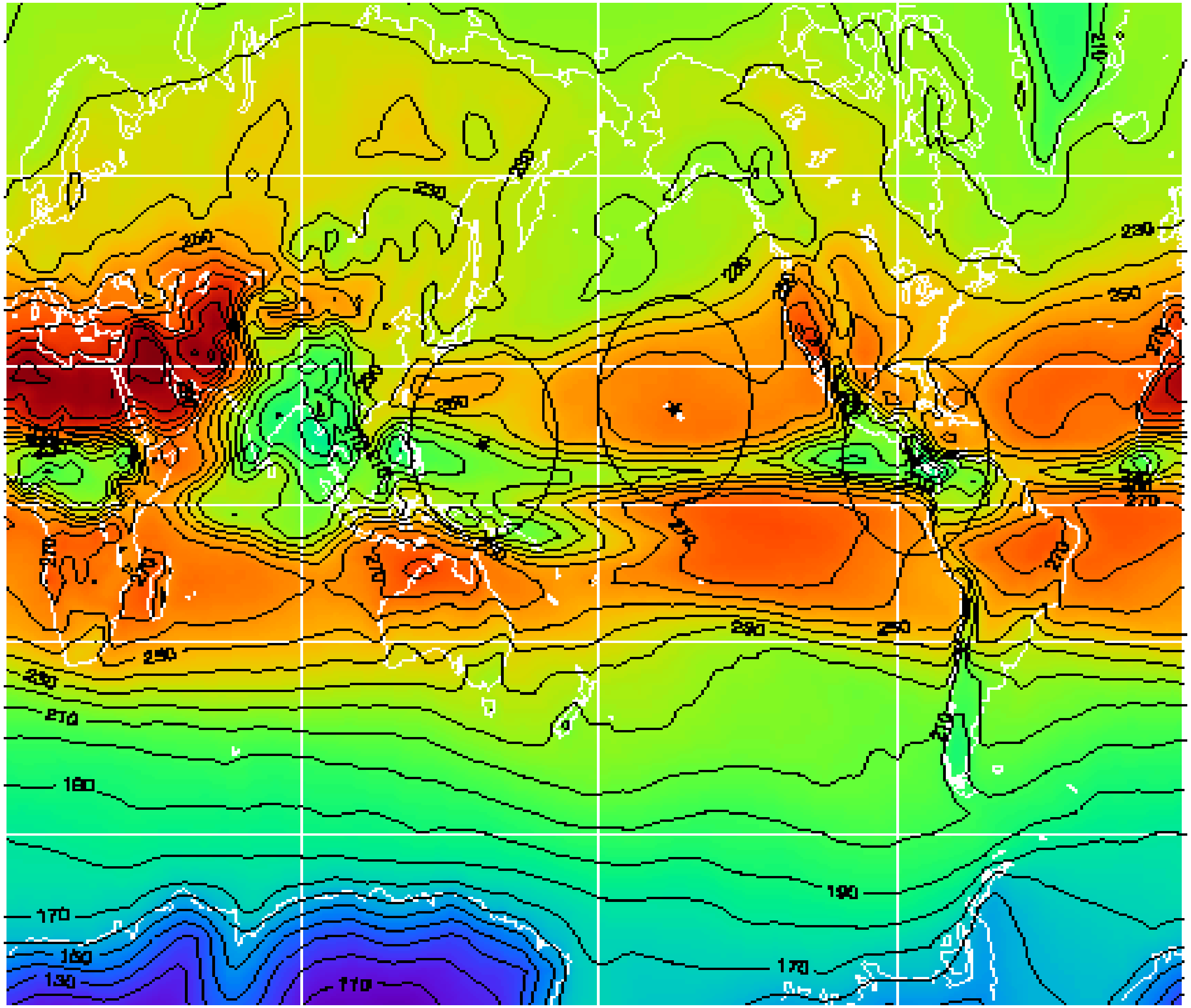


Matthews, A.J., 2000 *Quart. J. Roy. Meteor. Soc.*, 126, 2637-2652.

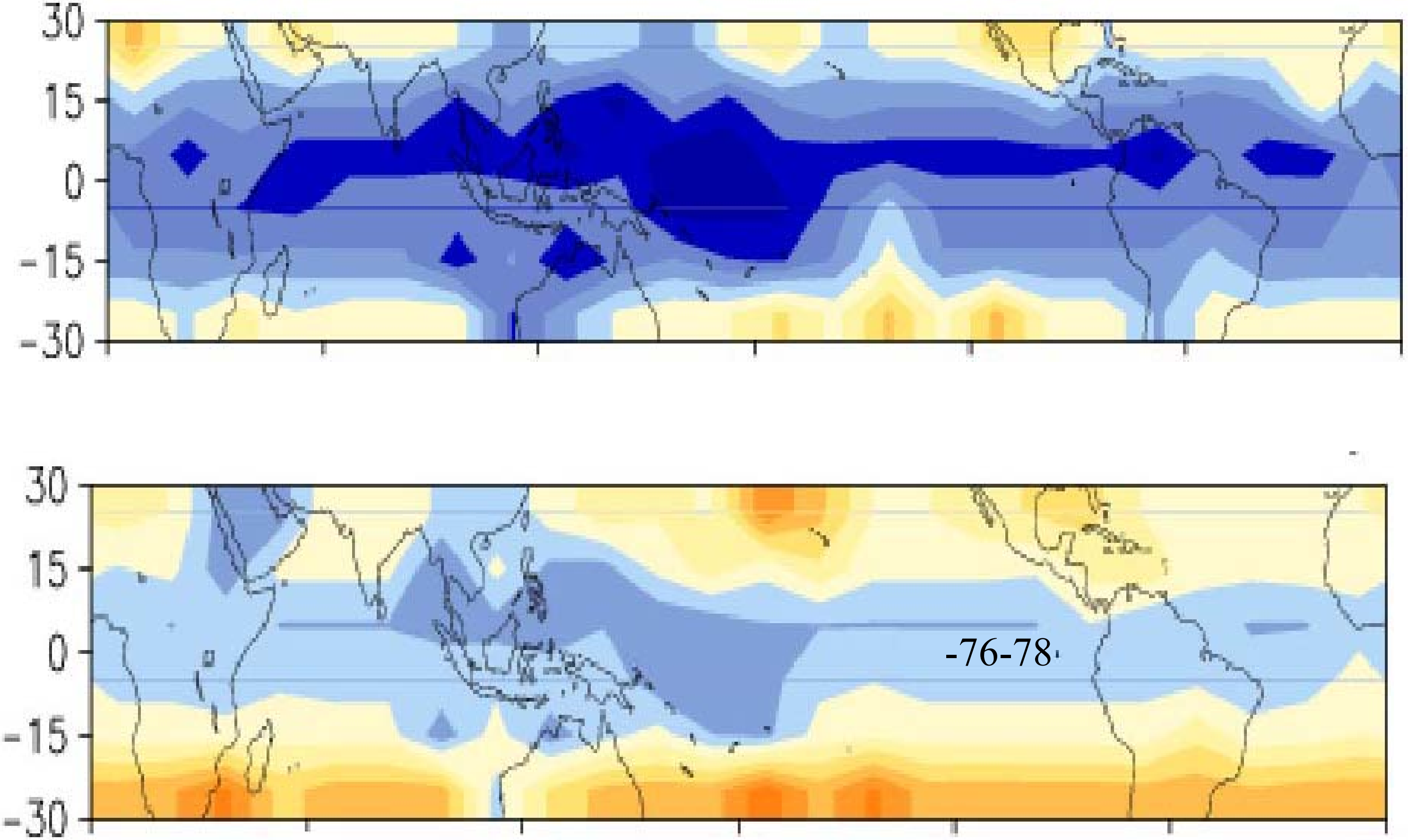
Criteria for NH summer mission

location	Singapore	Guam	Darwin	Kwajalein	Hawaii	Costa Rica
Lat/long	1.3°N, 103.9°E	13.4°N, 144.4°E	12.5°S, 130.6°E	9°N, 168°E	21.3°N, 157.9°W	10°N,276°E
runway/ hangers	yes	yes	yes	no	yes	Yes, canÕt hanger ER-2 and WB57
Close to maritime convection?	yes	marginal	no	no	yes	yes

Outgoing Longwave Radiation (W/m ^ 2) July 1979-1995



Lapse-RateTropopause Temperature *Julian oscillation.Quart. J. Roy. Meteor. Soc.*, 126, 2637-2652.



JAN

JUL

Seidel *et al.*, *JGR*, 106, 7857, 2001

Example of distribution of flights in a winter time mission in the tropical Western Pacific*

Number of multi-aircraft missions dedicated to goal*	Goal**	Description of flight plan
2	Obtain profile in mid-Pacific at all levels from boundary layer to mid-stratosphere	All aircraft fly as far south from Hawaii as possible along A-train path and return. Done in the initial transit, and in the final transit. Sample ozone, short-lived halocarbons, inorganic halogens, HO_x and NO_x radicals, aerosols, etc. as high as possible. Sample longitudinal structures in the the free troposphere of ozone, HOx and NOx radicals and their precursors, tracers of convection and lightning activity, etc
7	Profile tropopause cold pool region at all levels from boundary layer to mid-stratosphere. Examine TTL properties, and their relations to lower troposphere/stratosphere	Fly across tropopause cold pool with all aircraft along A-train path. Sample tropical tropopause layer, subvisible cirrus. Do multiple (3) legs with a radiation-measuring package at the tropopause to get tropopause cooling rates. Sample ozone, short-lived halocarbons, inorganic halogens, HO_x and NO_x radicals, aerosols, etc. as high as possible. Sample longitudinal structures in the the free troposphere of ozone, HOx and NOx radicals and their precursors, tracers of convection and lightning activity, etc.
5	Outflow sampling	Sample clouds, water vapor, tracers, and radiation in aged (hours-days) convective outflow and tropopause cold pool outflow.
3	Deep convection	Characterize maritime deep convection/anvil system, including convective mass fluxes, updraft speeds, anvil microphysics, radiative fluxes, turbulence, tracer distribution, aerosols, etc. We should be able to do these over a ship.

*not including transit flights, which will have science instruments in operation, and will be stacked if possible. ** it is assumed that all flights will coordinate with the A-train. While the example of flying along the spacecraft track is given in the Table, the actual flight plans might be cross track, or other patterns as requested by the satellite teams to meet their goals.*** no prioritization of the different goals, beyond the number of flights allocated to them, is intended

Example of distribution of flights in a summer time mission in the tropical Western Pacific*

Number of multi-aircraft missions dedicated to goal*	Goal**	Description of flight plan
5	Deep maritime convection	Characterize maritime deep convection/anvil system, including convective mass fluxes, updraft speeds, anvil microphysics, radiative fluxes, turbulence, tracer distribution, aerosols, etc. We should be able to do these over a ship.
2	Deep continental convection (if mission is from Costa Rica)	Characterize continental deep convection/anvil system, including convective mass fluxes, updraft speeds, anvil microphysics, radiative fluxes, turbulence, tracer distribution, aerosols, etc.
5	Examine TTL properties	Sample tropical tropopause layer, subvisible cirrus, relative humidities, ozone and its photochemical precursors, aerosols, radiative fluxes, etc. Do multiple (3) legs with a radiation-measuring package at the tropopause to get tropopause cooling rates. Sample ozone, short-lived halocarbons, inorganic halogens, HO_x and NO_x radicals, aerosols, etc to maximum altitude. Sample longitudinal structures in the the free troposphere of ozone, HOx and NOx radicals and their precursors, tracers of convection and lightning activity, etc.
3	Outflow sampling	Sample clouds, water vapor, tracers, and radiation in aged (hours-days) convective outflow.

*not including transit flights, which will have science instruments in operation, and will be stacked if possible. ** it is assumed that all flights will coordinate with the A-train. While the example of flying along the spacecraft track is given in the Table, the actual flight plans might be cross track, or other patterns as requested by the satellite teams to meet their goals. *** no prioritization of the different goals, beyond the number of flights allocated to them, is intended.

A tentative schedule, which must be carefully related to satellite launch schedules, is:

- **Western Pacific (NH winter – primary focus on TC3 goals): Winter 2004/2005**

- **Western or Eastern Pacific (NH summer – primary focus on CRYSTAL goals) : Summer 2005**

Issues to address

- Best location for missions; strategy for ENSO, Madden-Julian Oscillation
- Choice of suitable aircraft-esp in stratosphere
- Develop new instruments (Priority 1,2: GPS all AC; Acetone, HCHO, peroxide-4AC; forward scanning lidar-1 AC; BrO, ClO -1 AC; short lived organics, SO_2-1 aircraft; H_2O,O_3 lidar, DOAS profiler 1 AC)